EXPERIMENTAL POND CULTURE OF BROWN SHRIMP (*Penaeus aztecus*) IN POWER PLANT EFFLUENT WATER[1]

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ABSTRACT

The present study was designed to measure survival and growth of brown shrimp in ponds receiving a continuous flow of Galveston Bay water from the heated effluent of an electric power plant. Eleven 0.1-ha ponds were stocked with 5,000 postlarval brown shrimp (*Penaeus aztecus*) each. Five ponds were stocked in April and six in July, 1972. Our results were similar to those obtained in non-flowing ponds in that shrimp growth was slowed as mean length approached 100 mm and failure to control predation and competition markedly reduced yield. Nevertheless, our results show improved brown shrimp yields as compared to those reported for non-flowing ponds. Where predation and competition were controlled and supplemental food was provided, survival was 58-97%, growth was 1.2-1.4 mm per day, and yields were 318-596 kg per ha for periods of 10-12 weeks.

INTRODUCTION

The commercial shrimping industry along the South Atlantic

[1]This research was funded by the Houston Lighting & Power Company through Texas Agricultural Experiment Station Project 1869.

and Gulf Coasts is one of the most valuable fisheries in the United States. Production from the Gulf of Mexico in 1971 was over 103 million kg worth $136 million (U. S. Department of Commerce, 1972). In the past few years, however, the demand for shrimp in the United States has exceeded the available United States supply, causing a rise in imports. Thus, efforts to increase the shrimp supply through culture methods are of increasing interest. However, in the United States, efforts to rear brown shrimp (Penaeus aztecus) in ponds to marketable size have been primarily experimental and have had only limited success. Better success has been obtained with white shrimp (Penaeus setiferus) (Parker, 1972). However, at present the seed stock (postlarvae) of white shrimp are relatively scarce.

In this study brown shrimp were reared in ponds receiving a constant flow of heated water which had passed through a power station on the Texas Gulf Coast. Many previous studies involving the pond culture of shrimp have used ponds without a constant flow of water. Two experiments were conducted--one in the spring (April-July) and one in the summer (July-September). This study is part of a larger research project, studying the effects on selected organisms of water passing through a power plant. Pond work is also being conducted on blue crabs (Callinectes sapidus), oysters, and various species of fish. A cage study of several fish species is also in progress.

DESCRIPTION OF POWER PLANT AREA AND PONDS

The Houston Lighting and Power Company's Cedar Bayou power plant is situated on the highly productive Galveston Bay system. The plant, which is located on a peninsula separating the north ends of Galveston Bay and Trinity Bay, draws cooling water from the former via Cedar Bayou and discharges it into Trinity Bay through a dredged canal (Figure 1). The ponds used in this study were built near the start of the discharge canal (Figure 2). Each 0.1 ha pond is approximately 82 m long and 12 m wide. Pond depth gradually increases along its longitudinal axis from intake end to discharge end where the depth is 1.5 m. A 75 hp pump supplied all ponds with water from the discharge canal, each pond receiving approximately 114 liters per minute. This flow rate could flush the pond in about 1 week. When the pump was not operating the ponds received water by gravity flow at a rate of approximately 68 liters per minute. Water was constantly flowing into one end of the pond and discharged through a stand pipe at the other end. This standpipe could be laid over on its side to drain the pond by gravity.

EXPERIMENTAL RATIONALE

Our primary purpose in the first (spring) experiment was to determine what levels of shrimp survival could be expected with the facilities and water quality available. For this reason all

shrimp ponds were treated equally during the spring experiment, and one pair of ponds was harvested earlier than the rest in order to obtain an accurate measure of survival. Having determined that good survival was possible, our purposes in the summer experiment were to compare summer survival and growth with that obtained in spring, and to determine the effect of feeding levels on shrimp survival and growth in this continuous flow situation. Therefore, two ponds were treated like those in the spring experiment, while two other pairs received food at higher and lower rates, respectively.

POND METHODS

Preparation

Prior to stocking, the ponds were drained, sun-dried, and then refilled. Before refilling the pond a filter bag (20.5 meshes per cm) was clamped over the end of the inlet pipe to reduce contamination of the pond by foreign organisms. One of the ponds (no. 13) was not drained completely before stocking because depressions in the pond bottom near the standpipe held water which could not drain through the lowered standpipe.

Spring Experiment

On April 13 and 14, 1972, 5,000 postlarval brown shrimp were collected at the entrance of Galveston Bay with a hand-drawn beam trawl (Renfro, 1963). These shrimp were kept in plastic tanks while being acclimated from a salinity level of 25 ppt to 12 ppt during a 3-4 day period. The shrimp were then stocked at a pond salinity of approximately 12 ppt. At stocking these postlarvae averaged 11.0 mm in total length (tip of rostrum to tip of telson) and 0.003 g in total weight.

On April 18 and 19, 20,000 postlarval brown shrimp were obtained from the National Marine Fisheries Service Laboratory in Galveston, Texas. We acclimated these shrimp from 28 ppt to 12 ppt over a period of 9 days. These shrimp were stocked at a density of 5,000 per pond (50,000 per ha or 20,000 per acre) in four ponds, all with a salinity of approximately 12 ppt. At stocking the 10,000 postlarvae obtained on April 18 averaged 13.5 mm in total length and 0.019 g in total weight, while those collected on April 19 averaged 14.9 mm in total length and 0.021 g in total weight.

Summer Experiment

On July 11 and 12, 1972, 30,000 postlarval brown shrimp were again obtained from the National Marine Fisheries Service Laboratory in Galveston and these shrimp were stocked in six ponds at a density of 5,000 per pond. Prior to stocking, these shrimp were acclimated from 28 ppt to 19 ppt over an 11-day period and stocked in ponds with a salinity of approximately 17 ppt. The 10,000 shrimp obtained on July 11 averaged 12.1 mm in total length and 0.011 g in total weight while those obtained on July 12 averaged 12.5 mm in total length and 0.013 g in total weight.

Feeding, Sampling and Harvesting

During the initial month of both experiments the shrimp were not fed a supplemental food source on the assumption that natural food was abundant in the ponds. The shrimp were then fed a supplemental diet of Purina Trout Chow. The daily feeding rate for all ponds during the spring experiment was 10% of shrimp body weight. In the summer experiment two ponds received 0%, two received 10%, and two received 15% of shrimp body weight per day. The amount fed was based on survival estimates extrapolated from cast net catches. The spring ponds were first sampled a month after stocking (mid-May). Initial sampling consisted of catching 50 shrimp per pond twice a month with a cast net and recording total length. Starting in mid-June, 25 shrimp were sampled weekly with both weights and lengths being recorded. The summer ponds were sampled in the latter manner beginning 3 weeks after the stocking date. All measured shrimp were returned to ponds.

At harvest most shrimp were collected in bags placed over pond outlets in the drainage ditch. Seines were also used where pond drainage could not be completed by gravity flow.

To obtain samples of small benthic organisms, core samples 10 cm in diameter and 3.5 cm deep were collected from pond bottoms and washed through a screen with 0.5 mm aperture size. Organisms retained by the screen were examined at 7 to 30 X magnifications.

Physical data including surface and bottom water temperature, conductivity and dissolved oxygen were recorded approximately daily beginning April 21, 1972. These data were taken with a Hydrolab Model 6 portable surveyor system. Prior to April, trial surface and bottom readings were recorded for the intake, middle, and discharge areas of the ponds. No significant difference was observed in the physical parameters among the three locations. Thus, during this study, surface and bottom readings were taken only in the middle of each pond.

RESULTS AND DISCUSSION

Physical Data

Surface and bottom water temperatures were very similar throughout the study period (Figure 3). Thus, thermal stratification, if present, was not great. Pond temperatures ranged from 21.1 to 34.8 C for the spring experiment and from 27.3 to 35.0 C for the summer experiment. Temperatures recorded at the intake structure of the plant were taken as representing the ambient

water temperature. These temperatures, which ranged from 21.0 to 30.5 C in the spring and from 27.0 to 33.5 C in summer, were usually only 1-2 C cooler than pond temperatures. The discharge canal was usually 4-6 C warmer than the ponds, with temperatures ranging from 26.3 to 38.3 C in the spring and from 30.0 to 41.0 C in the summer. Apparently most of the heat added by the power plant was dissipated from the discharge water in transit to the ponds.

Dissolved oxygen was quite variable both with time and between ponds (Figure 3). For this reason only weekly extremes are presented in the graph. Values were usually greater at the surface than at the bottom of the pond. Dissolved oxygen in ponds ranged from 0.3 to 19.4 ppm in the spring experiment and from 0.0 to 20.0 ppm in the summer experiment. The greatest range in any pond was 19.1 ppm (0.3-19.4) during the spring and 19.6 ppm (0.4-20.0) during the summer. The smallest range in any pond was 6.2 ppm (3.6-9.8) during the spring and 12.8 ppm (1.1-13.9) during the summer.

During the spring experiment pond salinities were fairly constant till early May when heavy rains caused the values to drop to mid-May lows after which the salinities gradually rose till the time of harvest (Figure 3). The lowest pond salinity was 3.5 ppt while the highest level was 17.2 ppt. On May 12, mechanical failure shut down the pump supplying water to the ponds. The pump was soon fixed but was left off through May 24 because of the very low salinities in the discharge canal during this time. During this period (May 12-24, 1972), the ponds were fed by gravity flow only. It was roughly during this period that various degrees of stratification occurred in the ponds (Figure 3).

During the summer experiment the pond salinities showed a general increase throughout the summer. The lowest pond salinity was 14.6 ppt while the highest was 21.0 ppt. Slight stratification occurred during the summer.

Shrimp Survival and Growth

Spring experiment: Survival in the five ponds ranged from 43% to 75% (Table 1). The two ponds harvested early had better survival (69-75%) than the ponds harvested later (43-67%). Three of the ponds (nos. 9, 10, 12) which contained hatchery shrimp produced the highest survival (67-75%) of this experiment. The pond which contained shrimp caught from the natural environment showed a somewhat lower survival rate (58%). This may have have been due to the fact that the natural shrimp caught in the field were subjected to considerably more handling and more rapid salinity changes prior to stocking than were the hatchery shrimp. At harvest the pond (no. 13) with the lowest survival (43%) contained many cyprinodont fish (*Cyprinodon variegatus*) and was the only pond to have these fish

(Table 1). The difficultues in draining this pond prior to stocking have already been mentioned. At least one blue crab and several cyprinodont fish were observed in this pond before it was filled for stocking. The fish probably inflicted heavy shrimp mortalities during the early stages of the experiment. During the latter stages of the experiment these fish competed with the shrimp for food, for they were observed eating Trout Chow during feeding. Thus, the low survival in this pond is attributed to the predation and competition for food caused primarily by the cyprinodont fish.

Length curves indicate that the shrimp went through a period of early rapid growth followed by a period in which the rate of growth slowed (Figure 4). As a result, the greatest overall rates of growth were recorded for the two hatchery ponds (nos. 9, 10) that were harvested early (Table 1). Shrimp in both ponds grew at rates of 1.5 mm per day. In the other three ponds, which were harvested at approximately the same time, the growth rate ranged from 1.1 to 1.2 mm per day. In terms of weight the growth rate ranged from 0.11 to 0.13 g per day in the five ponds. The final lengths ranged from 91.8 (early harvest) to 111.3 mm and the final weights ranged from 5.83 (early harvest) to 11.04 g (Table 1). The number of whole shrimp per kg ranged from 91 to 172 (41-78 shrimp per pound) and the production in kg per ha ranged from 187 to 365 (165-322 pounds per acre) (Table 1). It should be noted that the pond with the lowest shrimp survival (no. 13) was also associated with the poorest growth (1.1 mm per day and 0.11 g per day). This can be attributed to the cyprinodont fish in this pond which competed with the shrimp for food.

Summer experiment: Survival in the six ponds ranged from 49% to 97% (Table 2) over a 73-76 day period. The pond with the lowest survival (49%) had an extremely high population (about 50,000) of Cyprinodon variegatus. This pond was the same one (no. 13) that had drainage problems in the spring experiment. As a consequence, some cyprinodont fish were present in the pond prior to stocking with postlarval shrimp. As in the spring experiment, low survival in this pond was probably due to the predation and food competition by the cyprinodont fish. Survival of fed shrimp which did not have a serious predator/competitor problem was higher (69-97%) than that of unfed shrimp (55-68%).

At harvest, final lengths ranged from 84.2 to 113.4 mm and final weights ranged from 4.39 to 12.25 g. Length curves (Figure 4) again show that the shrimp experienced a period of early rapid growth which then slowed as the shrimp approached 100 mm. The overall growth rates (Table 2) ranged from 1.0 to 1.4 mm per day and 0.06 to 0.17 g per day. This is a much greater variation than was found in the spring experiment (1.1-1.2 mm per day and 0.11-0.13 g per day for 80-day experiments). Part of this variation in summer growth rate can be attributed to different summer feeding

rates and part may be due to differences in faunal composition of the ponds. Shrimp fed 15% of their body weight grew faster (1.2-1.3 mm per day and 0.13-0.14 g per day) than those that were unfed (1.0-1.2 mm per day and 0.07-0.11 g per day) (Table 2). The shrimp fed at a rate of 10% would be expected to show growth rates intermediate between those fed at 0% and 15%. However, they showed the best (1.4 mm per day and 0.17 g per day) and worst (1.0 mm per day and 0.06 g per day) growth. The pond with the worst shrimp growth was the cyprinodont pond already mentioned. Thus, competition for food probably caused the poor growth. The pond with the best growth (no. 11) differed from the other ponds in having a large population of mysid crustaceans and these may have been an important source of shrimp food. This possible effect of species composition on the growth rate of the shrimp is further supported by the fact that there were variations in shrimp growth between ponds prior to supplemental feeding.

The number of whole shrimp per kg ranged from 81 to 228 (37-103 shrimp per pound) and the production in kg per ha ranged from 106 to 596 (94-526 pounds per acre) (Table 2). The production in kg per ha for shrimp fed 15% of their body weight (335-375) was better than for unfed shrimp (163-218). Shrimp fed 10% of their body weight would be expected to produce a yield intermediate to those being fed 0% and 15%; however, the production values for the 10% feeding rate are again the best (596 kg per ha) and worst (106 kg per ha). The reasons for this are probably those mentioned above in relation to growth rates.

Conversion Rates

Final conversion rates for the five spring ponds ranged from 0.7 to 2.9 g of feed per g increase of shrimp (Table 1). The rates for the four summer ponds that were fed ranged from 2.0 to 3.9. More and Elam (1970) reported food conversion rates ranging from 5.3 to 14.0 in pond studies with brown postlarvae while Elam and Leary (1972) cited values ranging from 4.2 to 14.0 kg of feed per kg of shrimp.

Condition Factor

The relative well-being and health of shrimp is expressed by the coefficient of condition (K). This factor is derived from the formula:

$$K \doteq \frac{W \times 10^6}{L^3}$$

where W = weight in grams and L = length in millimeters. In the spring experiment all the final shrimp conditions were approximately the same, ranging from 7.5 to 8.0 (Table 1). In the summer experiment, final shrimp conditions for the two ponds in which shrimp were fed at a rate of 15% of their body weight were higher (8.1 and 8.2) than for the unfed shrimp (7.3, 8.0) (Table 2). The shrimp fed at a rate of 10% showed the best (8.3) and one of the worst (7.3) final conditions (the latter representing the "cyprinodont" pond). Thus, supplemental feeding seems to be necessary to produce the healthiest shrimp. The condition of these pond shrimp was compared with the condition of shrimp trawled from the Gulf of Mexico (raw data - Dr. Richard Neal, National Marine Fisheries Service, Galveston, Texas). Comparisons by size classes indicate that for every size class the pond shrimp had higher coefficients of condition than did the shrimp caught in the Gulf (Figure 5).

Wheeler (1967) also found circulating water favorable to shrimp condition. He reported better condition for shrimp in a circulating water pond (7.2) than for those in a static water pond (6.9).

Benthos

Some unidentified insect larvae, polychaetes, and barnacles were found in pond bottom samples, but the most abundant species was the bivalve (*Congeria leucophaeta*) (Conrad's false mussel). During the spring experiment ponds 10 and 12 had large *Congeria* populations, pond 11 (natural environment shrimp) had a smaller *Congeria* population, while *Congeria* was not found in samples from ponds 9 and 13 (Table 3). Ponds with the greatest abundance of *Congeria* showed the least evidence of stratification, while the ponds with the lowest abundance of *Congeria* showed the greatest stratification. The relationship between abundance of *Congeria* and the degree of pond stratification is not so clear during the summer. During that period the pump was never turned off for more than a few days, so physical conditions were not nearly so favorable for stratification as they were during spring when the pump was off for 12 days. The *Congeria* populations apparently did not adversely affect the dissolved oxygen levels in the ponds or the growth and survival of the shrimp.

General Remarks

These results are encouraging compared to those of previous attempts to raise postlarval brown shrimp in ponds. Most previous studies have resulted in rather poor survival, or if survival was high (50% or higher) growth was generally poor. Wheeler (1968), More and Elam (1970), Parker (1970), Elam (1972), and Elam and Leary (1972) reported generally good growth but poor survival in pond work using postlarval brown shrimp for stocking. Elam and Leary (1972) concluded that the ". . . survival rates . . . of postlarval shrimp have been very poor in growing ponds. This low survival has resulted in good growth rates of postlarval shrimp." Broom (1969) obtained fair survival (45%) with a production of 162 kg per ha. In a progress report, Klussmann and Parker (1972) reported good growth (1.2 mm per day over an 83-day period) but no survival data was reported. Parker (1972) further reported

that in 90 days brown shrimp yielded less than 280 kg per ha at the same stocking density that produced upwards of 896 kg per ha of white shrimp (*P. setiferus*).

In contrast to these results, our present 10-12 week studies coupled fairly good growth (1.0-1.4 mm per day) with fairly good survival (43-97%), yielding 106-596 kg per ha (94-526 pounds per acre). If the poor results of the "cyprinodont" pond (no. 13) are ignored for both experiments (due to the known presence of extra predators and competitors), the growth was 1.0-1.4 mm per day, survival was 55-97%, and yields were 163-596 kg per ha (144-526 pounds per acre). If the low rates from the unfed ponds are also ignored, then growth was 1.2-1.4 mm per day, survival was 58-97%, and yields were 318-596 kg per ha (280-526 pounds per acre). These latter results are associated with supplemental feeding and adequate control of predation.

A laboratory study by Zein-Eldin and Aldrich (1965) for postlarval brown shrimp reported a growth rate of 0.8 mm per day at 25 C and 1.1 mm per day at 32 C for a 28-day period. This growth rate in the lab does not equal the growth rate obtained in this study (1.8-2.6 mm per day) over the same time period.

The study by Zein-Eldin and Aldrich (1965) also indicated that the rate of growth in postlarval brown shrimp increased with increasing temperature. Our study showed that during the first 4 weeks of growth the summer shrimp (average summer temperature = 30-32 C) grew more rapidly than did the spring shrimp (average spring temperature = 25-27 C). During this period spring shrimp grew at a rate of 1.8-1.9 mm per day while the summer shrimp grew at a rate of 1.9-2.6 mm per day. The more rapid early growth of the summer shrimp is probably due to the warmer summer water temperatures. In both spring and summer experiments shrimp growth was markedly slowed as mean length approached 100 mm. Although the summer shrimp grew more rapidly during the early phases of growth, the growth rates of the entire spring and summer experiments were similar.

Low salinity acclimation may have contributed to relatively high survival rates (55-97% where predation was controlled) obtained in this study, where postlarvae were acclimated to 12-19 ppt prior to stocking in ponds. Wiesepape et al. (1972) have suggested that low salinity acclimation is a better preparation for heat resistance then is acclimation at higher salinities. Thus acclimating postlarvae to low salinities before transfer to rearing ponds would better prepare the shrimp to survive increases in temperature. It would be interesting to know if low salinity acclimation provides shrimp with other benefits in addition to heat resistance, for example resistance to low dissolved oxygen.

The flowing water system employed in this work seemed to have beneficial effects. It undoubtedly helped prevent more serious pond stratification and low dissolved oxygen by contributing to water circulation. The flowing water also provided a continuous supply of natural food for the shrimp so that fertilization of the ponds or supplemental feeding was unnecessary during the first month after stocking. Finally, the slight residual heat in the discharge water from the power plant may have been beneficial in promoting early growth.

Several difficulties must be overcome before brown shrimp farming can be considered economically feasible. More work must be done to determine necessary feeding rates and the best type of supplemental feed. Also it is evident from this study that good pond drainage is extremely important both in controlling predators and competitors, and in eliminating harvesting difficulties.

Very recent results of Parker and Holcomb reported at this meeting demonstrate excellent yields for several species of white shrimp in Texas ponds. Perhaps white shrimp are better adapted than brown shrimp for pond culture as we now know it. If present problems of seed stock scarcity can be overcome, the possibility of further increases in yields by culturing white shrimp in flowing ponds presents an attractive prospect for future research.

ACKNOWLEDGEMENT

We appreciate the help of the following people: Mrs. G. A. Watson, J. D. French, G. H. Gilmore, P. Hammerschmidt, R. K. Keiser, Jr., R. W. Luebke, J. B. Welsh, Drs. R. A. Neal, F. G. Schlicht and R. K. Strawn.

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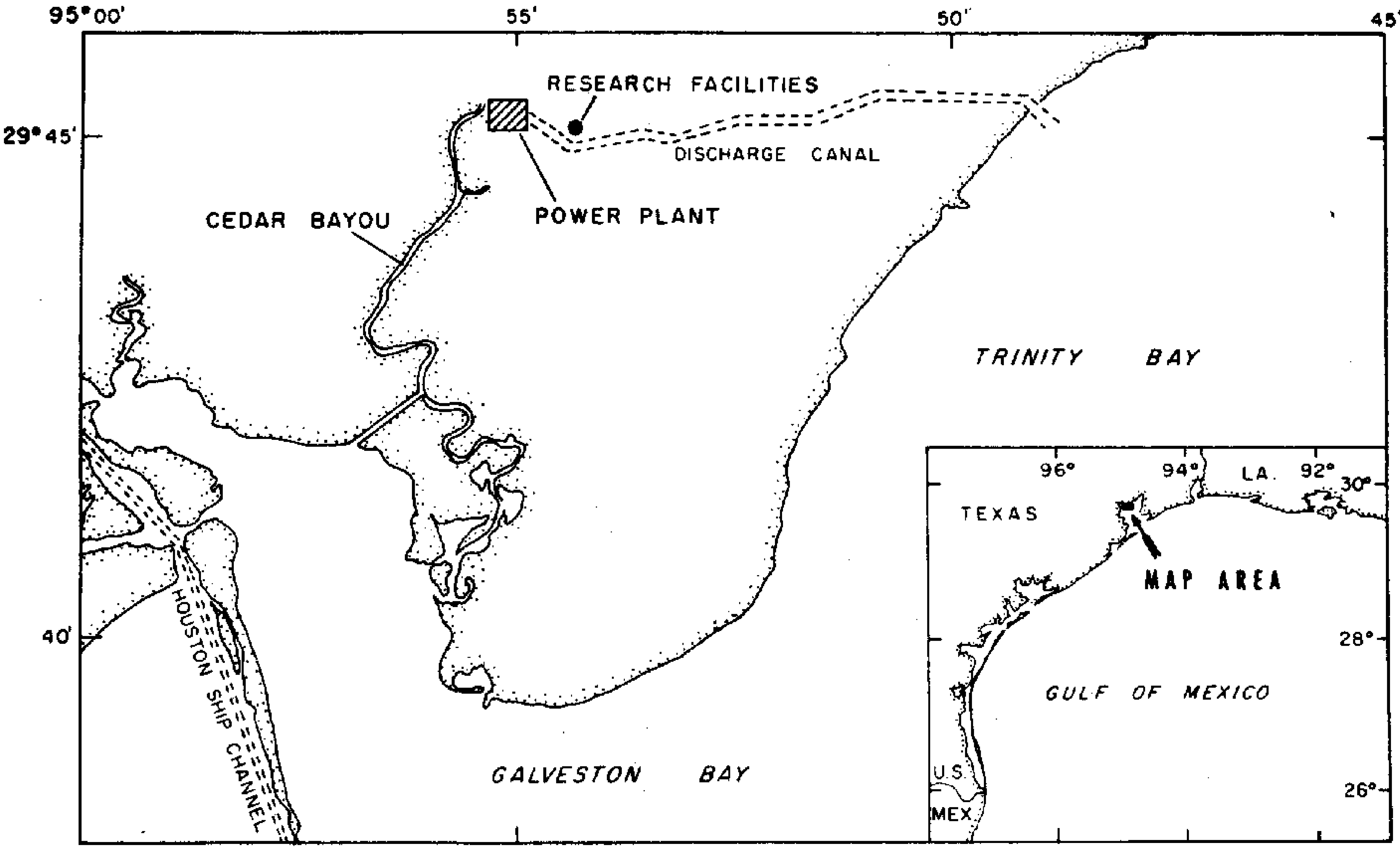

Figure 1. Location of research facilities.

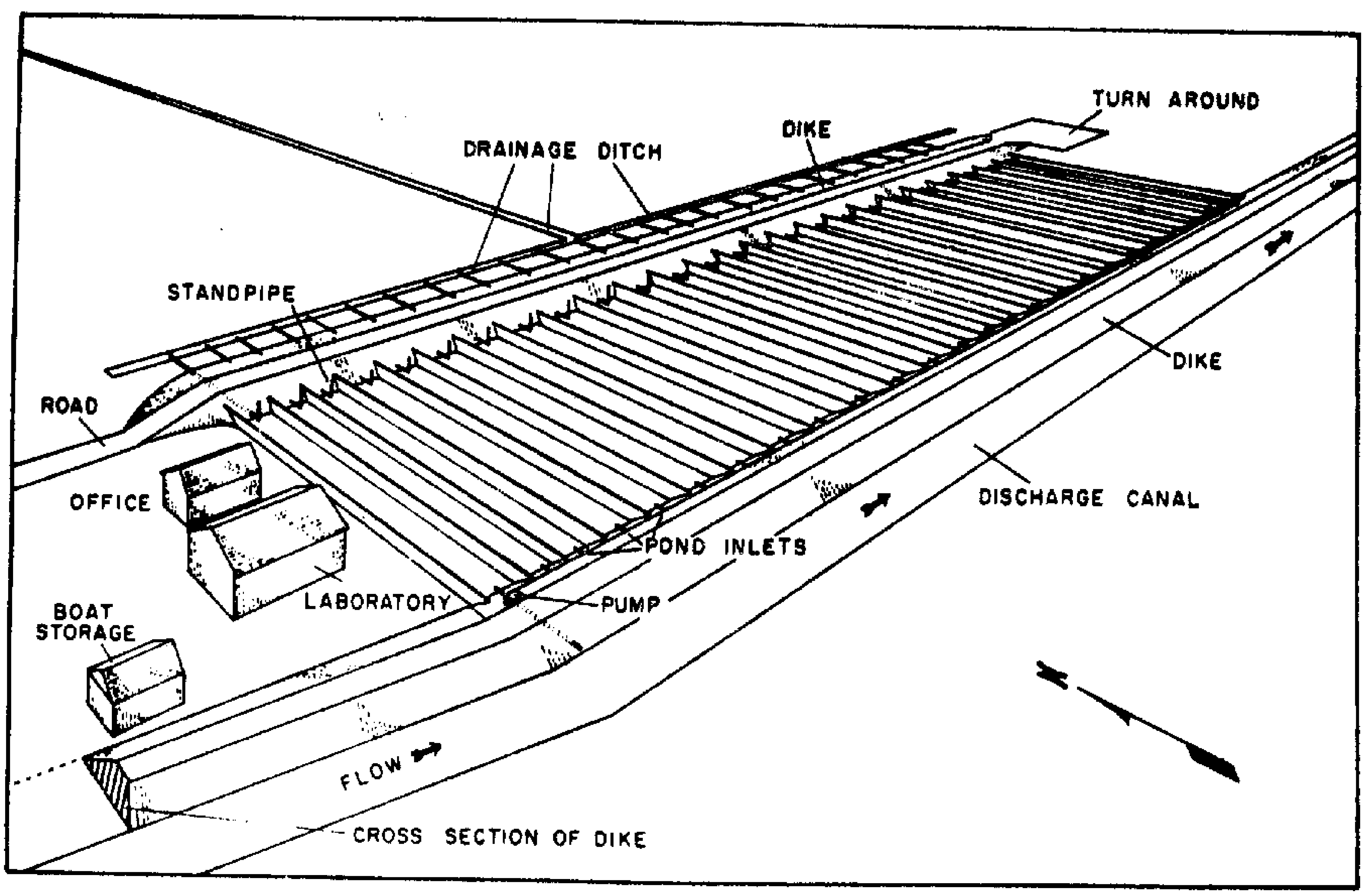

Figure 2. Arrangement of ponds near Cedar Bayou.

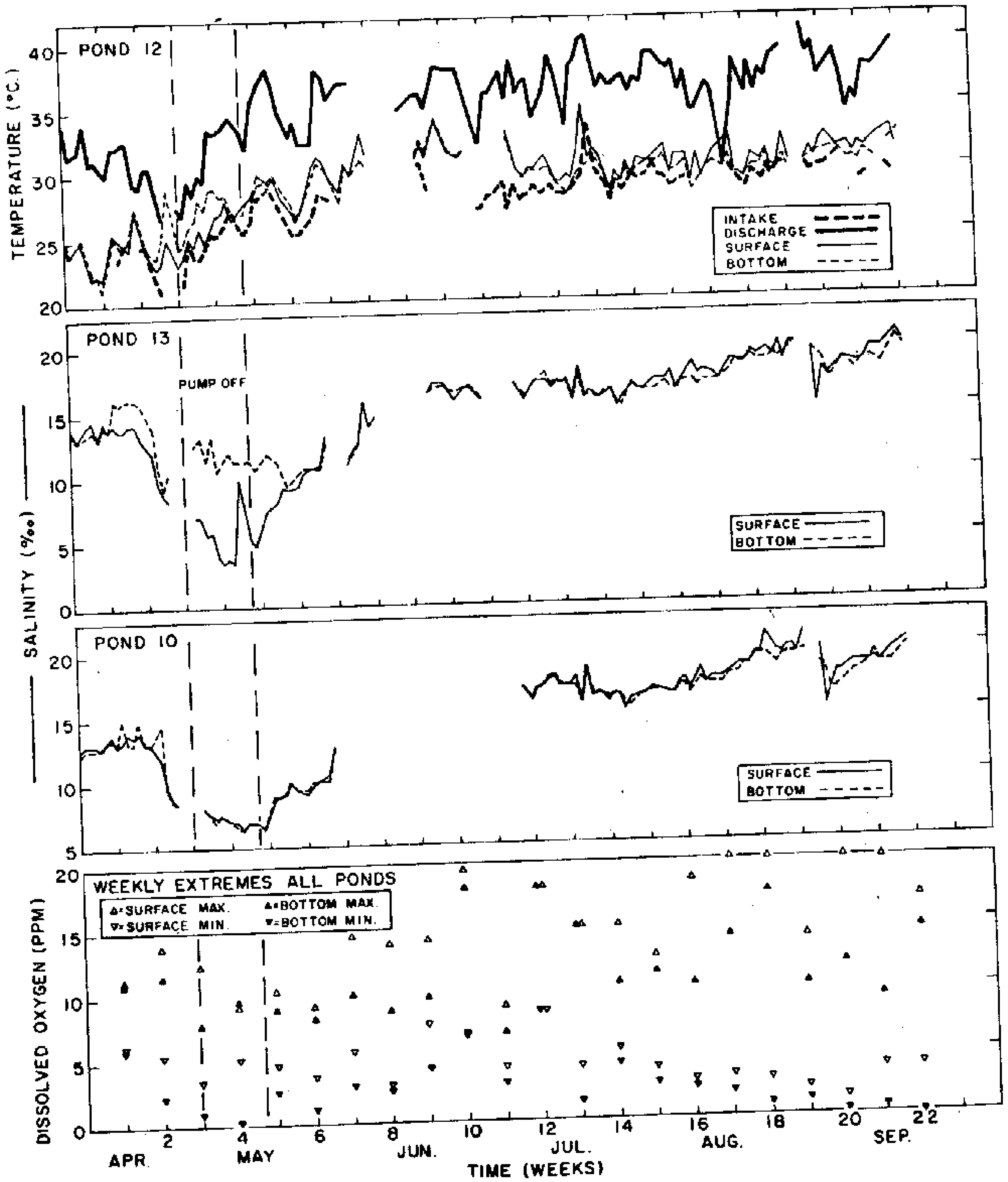

Figure 3. Temperature, salinity, and oxygen levels in ponds during spring and summer experiments.

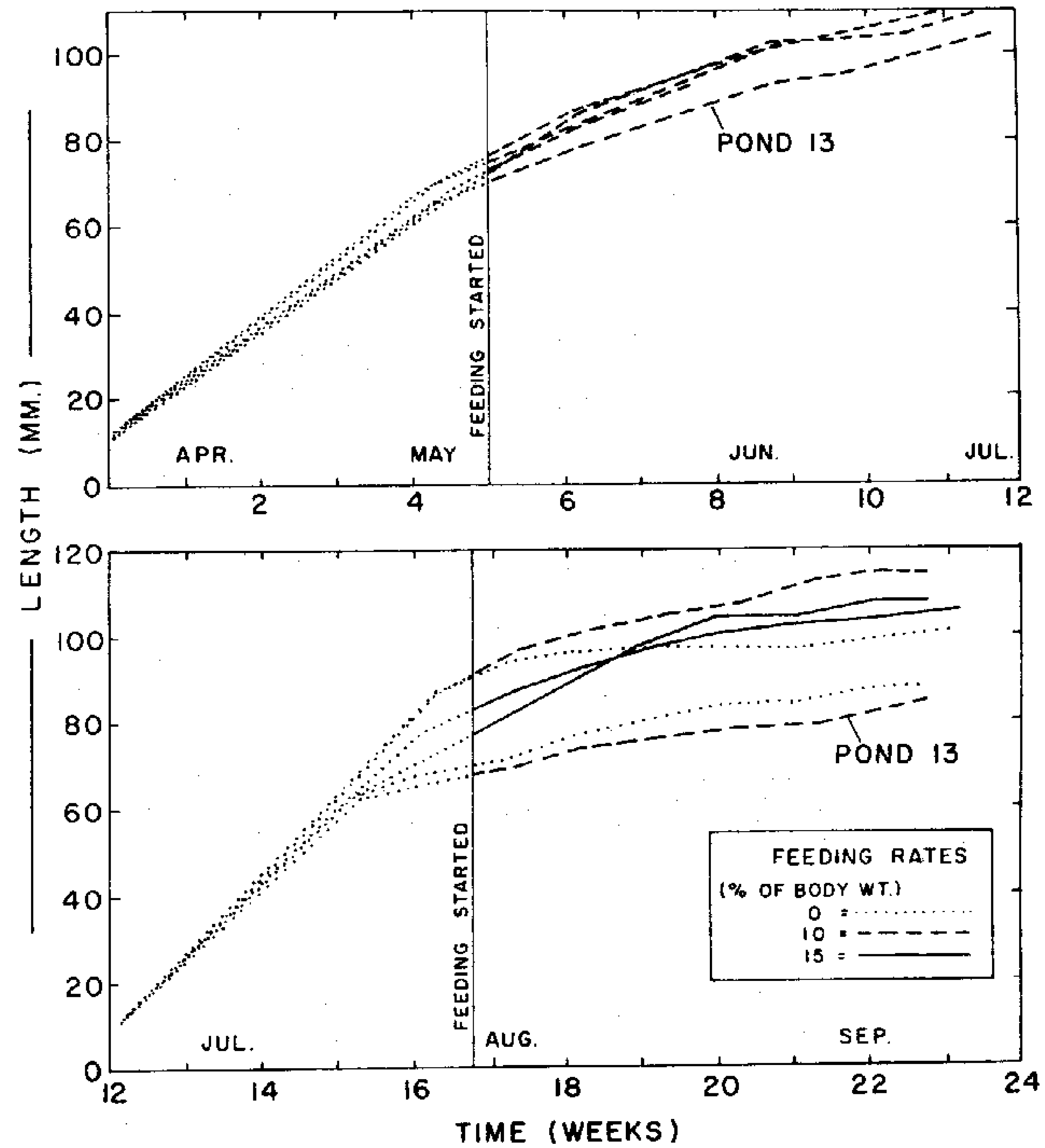

Figure 4. Growth of brown shrimp during spring and summer experiment.

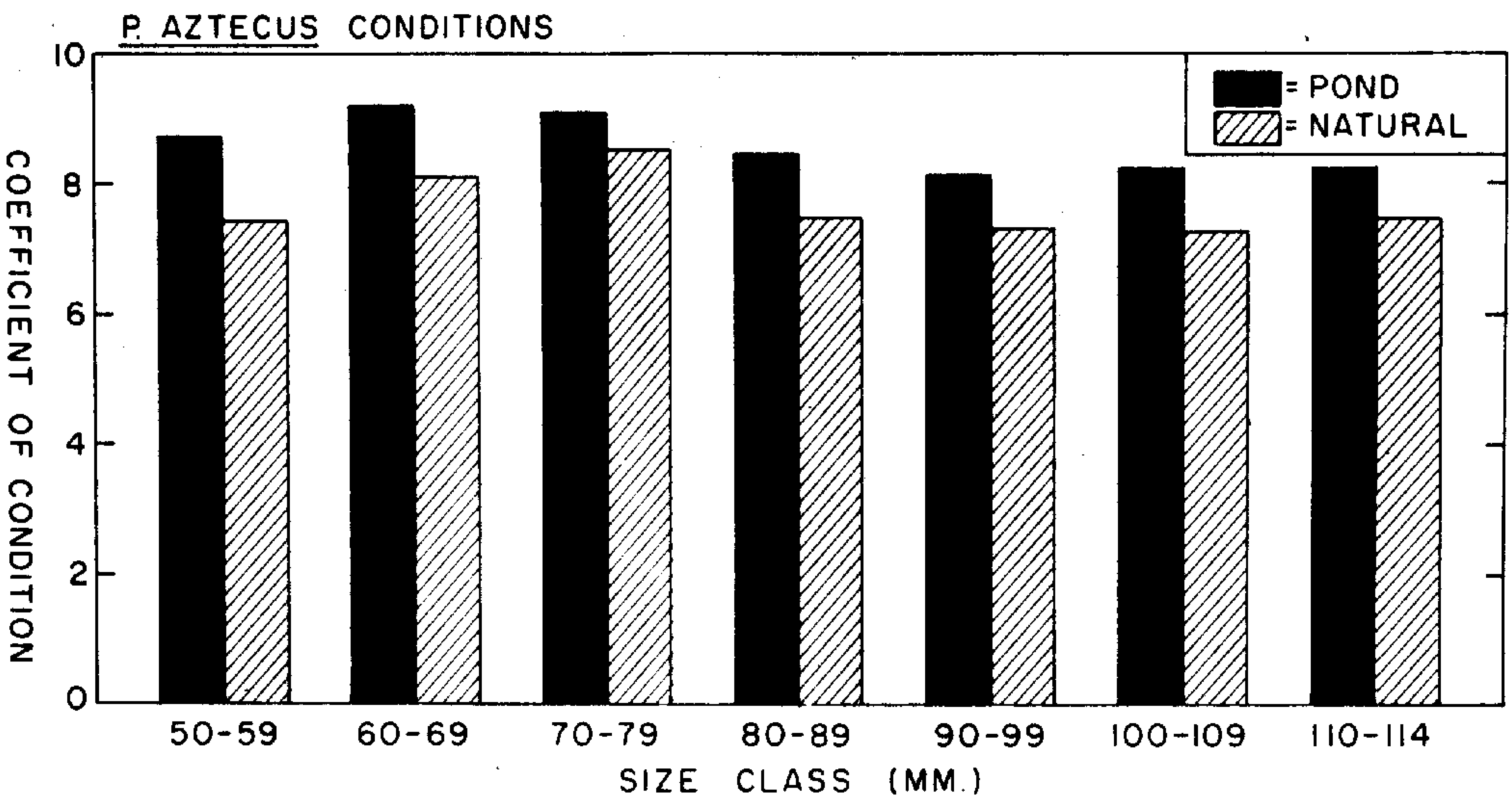

Figure 5. Condition of brown shrimp: ponds vs. nature.

Table 1. - Results of spring experiment

Pond number	Length of experiment (days)	Feeding rate (% of body wt.)	Percent survival	Harvested organisms other than shrimp	Growth mm/day	Growth g/day	Conversion	Final condition	Shrimp/kg	Kg/ha
9	51	10	69	1 <u>Callinectes sapidus</u>	1.5	0.11	1.1	7.5	172	201
10	58	10	75	3 <u>C. sapidus</u>	1.5	0.13	0.7	7.7	129	291
11*	84	10	58	2 <u>C. sapidus</u> 500 <u>Palaemonetes sp.</u> 3,000 <u>Rhithropanopeus harrisii</u>	1.2	0.13	1.5	8.0	91	318
12	81	10	67	4 <u>C. sapidus</u> 1 <u>Dorosoma cepedianum</u>	1.2	0.13	2.4	7.9	91	365
13	79	10	43	7 <u>C. sapidus</u> 1 <u>D. cepedianum</u> 1 <u>Paralichthys lethostigma</u> 500 <u>Cyprinodon variegatus</u>	1.1	0.11	2.9	8.0	115	187

*Stocked with postlarvae collected from the field.

Table 2. - Results of summer experiment

Pond number	Length of experiment (days)	Feeding rate (% of body wt.)	Percent Survival	Harvested organisms other than shrimp	Growth mm/day	Growth g/day	Conversion	Final condition	Shrimp/ kg	Kg/ha
9	73	0	68	11 *Callinectes sapidus*	1.0	0.07	-	7.3	208	163
12	75	0	55	6 *C. sapidus*	1.2	0.11	-	8.0	126	218
11	73	10	97	3 *C. sapidus* 3,000 *Rhithropanopeus harrisii* 2,500 *Palaemonetes* sp. 500,000 mysids	1.4	0.17	2.0	8.3	81	596
13	73	10	49	3 *C. sapidus* 50,000 *Cyprinodon variegatus*	1.0	0.06	3.3	7.3	228	106
8	76	15	69	10 *C. sapidus* 5 *Gobiosoma bosci* 1,000 *Poecilia latipinna* 2,500 *Menidia beryllina* 1,000,000 *Palaemonetes*	1.2	0.13	3.9	8.2	104	335
10	74	15	74	9 *C. sapidus*	1.3	0.14	3.0	8.1	99	375

Table 3. - Vertical stratification and *Congeria* populations in shrimp ponds

	Spring Experiment			Summer Experiment		
Pond number	Bottom minimum oxygen level (ppm)	Maximum salinity difference between surface and bottom (ppt)	*Congeria* per 80 sq cm	Bottom minimum oxygen level (ppm)	Maximum salinity difference between surface and bottom (ppt)	*Congeria* per 80 sq cm
8	-	-	-	0.0	3.7	0
9	0.6	5.0	0	1.0	4.8	0
10	3.9	2.4	39	0.6	3.0	36
11	1.0	4.1	7	1.1	1.8	7
12	2.4	2.6	82	0.6	3.3	212
13	0.3	8.2	0	0.2	3.7	1